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Artikel: The legacy and effect of Prof. Dr. H. H. Schmid on photogrammetry in the United States

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das PAGEOS-Projekt wurde bisher einmalig und erstmals ein System von global verteilten Fundamentalpunkten nach dem geometrischen Prinzip der Satellitengeodäsie mit astronomisch orientierten photogrammetrischen Strahlenbündeln bestimmt. Die dabei benutzten strengen mathematischen und instrumentellen Modelle sowie die statische Interpretation der Ergebnisse können als Vorbild für Folgeprojekte und für Verbesserungen der Methode benutzt werden.
In der PAGEOS-Triangulation werden Sterne als Passrichtungen verwendet. Diese stehen ohne Kosten zu jeder Zeit und an jedem Ort zur Verfügung (wenn optische Sicht vorliegt). Sterne können auch nicht wie Satelliten abgeschaltet, zerstört oder weggeschafft werden. Der passive Ballonsatellit enthält keine Apparaturen, er ist daher verhältnismässig billig und braucht keine Wartung.
Räumliche Netze mit orientierten Richtungen lassen sich derzeit mit geringerer Genauigkeit bestimmen als Strecken. Gründe hiefür liegen in der Szintillation, in der Refraktion, den Fehlern der Bildkoordinatenmessungen, im photographischen Prozess und der Ungenauigkeit in den Sternkatalogdaten. Sie tragen jedoch zur Bildung eines räumlichen Netzes in höherem Masse bei als Strecken. Denn für orientierte Strecken sind (theoretisch) neben den Koordinatenverbesserungen nur die Parameter einer Verschiebung als Unbekannte einzuführen, für Strecken jedoch zusätzlich noch Drehparameter. Daher erscheint es sinnvoll, für die Bestimmung der geometrischen Form eines Netzes vor allem Strecken, für die Orientierung jedoch Richtungen zu benutzen.
Das PAGEOS-Weltnetz ist ein wesentlicher Beitrag zu den Anfängen der Satellitengeodäsie und bezeichnet eine Entwicklungsstufe dieser Disziplin. Es hat die Folgeverfahren gestützt und steht derzeit als abgeschlossenes, einsatzfähiges, transparentes Verfahren für geodätische Folgeaufgaben zur Verfügung.
Diese Aufgaben betreffen vor allem die Schaffung von Kontrollpunkten in lokalen Bereichen, können aber auch in der Verbesserung der Gestirnskoordinaten sowie in Beiträgen zur Orientierung eines globalen Referenzsystems liegen. Im PAGEOS-Weltnetz wird die klare, transparente, mehrfach kontrollierte und in allen Phasen überschaubare Methode der klassischen Triangulation fortgesetzt. In diesem System werden begehbare Kontrollpunkte bestimmt, seit langem bekannte und immer verfügbare sichtbare astronomische Ziele und einfache, nur reflektierende Ballonsatelliten benutzt. Es unterscheidet sich dadurch von anderen Verfahren, welche eine Fläche bestimmen, die es in der Natur nicht gibt (das Geoid), die an der Erdoberfläche, auf der wir leben, nicht interessiert sind und die Orientierung der Aussagen mit Zielen (Quasaren) durchführen, die wir nicht sehen und deren Struktur und Langzeitverhalten nicht bekannt sind.
Wohl aus all diesen Gründen wurde in Japan ein Ballonsatellit EGP (Experimental Geodetic Payload) entwickelt, der 1986 gestartet wird und sowohl für die Messung von astronomisch orientierten Richtungen nach dem im PAGEOS-Weltnetz benutzten Verfahren als auch für Lasermessungen geeignet ist. Es ist anzunehmen, dass durch diesen Satelliten eine Wiederbelebung und wahrscheinlich auch eine Weiterentwicklung der geometrischen Verfahren der Satelligengeodäsie erfolgen wird.
Besondere Beachtung verdient auch die Tatsache, dass H. Schmid ein Verfahren der photogrammetrischen Raumtriangulation den bei der Stellartriangulation vorliegenden Verhältnissen angepasst hat. Denn damit wurde das hohe Leistungspotential dieser Disziplin ersichtlich und der Nachweis erbracht, dass die erst nur für topographische oder Katasteraufgaben eingesetzte Photogrammetrie auch Aufgaben der höheren Geodäsie zu lösen vermag und daher auch als Werkzeug dieser Disziplin angesehen werden kann. H. Schmid gebührt das Verdienst, diese Entwicklung eingeleitet und an einem spektakulären Beispiel erfolgreich eingesetzt zu haben. Ohne Zweifel hat er sich damit ein Monument geschaffen, das von seiner Tätigkeit auch in späteren Zeiten Zeugnis ablegen wird.

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The Legacy and Effect of Prof. Dr. H. H. Schmid on Photogrammetry in the United States

Ch. C. Slama, R. H. Hanson

It is a difficult task to single out one individual as being the sole innovator or creator in a complex and multi-disciplined science such as photogrammetry. When advances are made in photogrammetry, they are usually brought about by lengthy processes involving many individuals and organizations. In other words, the evolution is normally slow and the process of change covers a period of years. On the other hand, most attempts to improve on existing systems in photogrammetric practice are usually initiated and spurred on by only a few people who have the insight to recognize a potential improvement and the motivation to see the process through to the end. During his thirty years in the United States, Dr. H. H. Schmid played a major role as both an innovator and taskmaster in the sciences of photogrammetry and geodesy. His unique general appreciation of precision, ability to recognize important and critical aspects of the problem at hand, and engineer's approach to the solution, made him a leader in the field. All these characteristics, coupled with a dynamic personality, led to a working environment among his colleagues which encouraged competition, loyalty, and most importantly, results.
The science of photogrammetry in the United States has made giant strides over the past 30 years and much of the preliminary work can be attributed to H. H. Schmid. Foremost, in the minds of those who worked with him, was his early recognition of the application of Von Gruber's collinearity equations as the basic mathematical definition of photogrammetric reconstruction. In spite of the fact that large main-frame digital computers were not yet perfected, he possessed the foresight to envision applications of these equations to solutions of large photogrammetric networks that today are commonplace.

These equations form the basis for most modern applications of photogrammetry from analytical block triangulation to analytical plotting instruments for the extraction of data. In fact, in most photogrammetric literature today, they are usually referred to as "those well-known collinearity equations". Yet, very few people in the 1950's had the foresight to envision these same equations being solved in real-time over fifty times per second in analytical plotters. In ballistic trajectory measurements, the intersection form of collinearity was used in the 50's, but all of the solutions were found using hand calculators, patience, and crowds of employees with sore fingers. With the advent of the ORDVAC and BRLESC digital computers, along with pseudo-languages such as FORAST, came the opportunity to solve relatively large systems of equations entailed in ballistics. In addition, these devices spurred the imagination of Dr. Schmid in that he could envision the application of photogrammetry for world-wide triangulation using satellites photographed against a star background and the universal application of photogrammetry for geodetic densification of ground control. Through his leadership and tenacity, both became a reality in the United States. During the period 1964 to 1974, the Coast and Geodetic Survey (under the technical direction of Dr. H. H. Schmid) completed a world-wide survey which included the determination of the precise positions of 44 stations evenly spaced around the Earth. In the most recent issue of "Standards and Specifications for Geodetic Control Networks" issued by the Federal Geodetic Control Committee, photogrammetric ground control surveys are recognized and specified for the first time.

One common aspect of both satellite triangulation and geodetic applications of photogrammetry is the need for the absolute maximum in mensuration precision. Dr. Schmid's steadfast quest for the "micron" inspired his co-workers to seek the ultimate in instrument design, calibration, operation, and environment. More importantly, they acquired a respect, even a reverence, for precise measurement. The desire to produce measurements of the highest quality extended into the production area where the tedious task (in world wide satellite triangulation) of making over 1.2 million double image-measurements was performed. This inspired dedication of 34 comparator operators resulted in a mean error of pointing for all these measurements of about $\pm$ 1.63 micrometers – a feat difficult to equal. This attitude prevails even today as evidenced by the results of geodetic applications of precision photogrammetry at the National Ocean Survey. As mentioned earlier, measurement attitude was foremost, but another attitude that was inspired by Dr. Schmid was that of optimum instrument performance. For instance, when inconsistencies were detected early in the measuring process, it was discovered that (even in a controlled environment) body heat generated by the operator was contributing to instabilities in the comparator. Unfortunately, measurement technology of that day employed the precision screw as the basis for length. The problem, however, was found to be in the location of the reference mark and the solution in a redesign of the optics of the instrument. Others might have accepted the problem as insurmountable.

An early indication of Dr. Schmid's zeal for the optimum in mensuration was exhibited during his tenure at the Aberdeen Proving Grounds, where he was performing research in ballistic trajectory measurements. Precision comparators specifically designed for photogrammetric applications were just beginning to appear on the scene, but two-dimensional standards over the large formats involved for use as calibration devices were not readily available. One could procure a so-called precision "glass grid" with the

Members of the Geodetic Laboratory, c. 1974. From left to right, F. Morrison, J. Lucas, A. Pope, B. Copland, B. Chovitz, A. Miller, Dr. Schmid, C. Slama, E. Schmid, L. Gulick, M. Lawrence, F. Fulop, E. Andree, H. Poetzschke, R. Hanson. Photograph courtesy of F. Morrison.

understanding that the positional accuracy of the etched lines was limited by the mechanical deficiencies of the ruling engine used. In addition, there was always the question of perpendicularity of the two coordinate directions. To solve the problem, Dr. Schmid again took the engineer's approach and started with the basics. That is, he procured one highly precise standard scale on glass and used this, in combination with the comparator optics, to measure all combinations of distance between the etched markings on the grid in the form of a "trilateration". Further, he then developed a unique least squares "free adjustment" to finally estimate the true coordinates of the calibration grid. The resulting standard became the ideal criterion for all subsequent photogrammetric instrument calibrations at the Coast and Geodetic Survey and is still in use today – a testimony to the validity of the original work.

Perhaps the best indications of the effects an individual has on his profession are found in the honors and awards bestowed on him by his colleagues and institutions. Among the major awards given to Dr. Schmid in the United States, the citation that accompanied the Gold Medal (the highest scientific award given by the Department of Commerce) best expresses the accomplishments for which he was honored. The citation as printed in the program of the 18th annual honor awards ceremony on February 15, 1966, reads:

> "Dr. Schmid is a world authority on geometric geodesy and photogrammetry who has made outstanding contributions to science and technology in the United States, and to programs of the Coast and Geodetic Survey and the Department of Commerce. He is credited with solving the basic physical and theoretical problems of three-dimensional geodesy and photogrammetry, including the effective development of mathematical formulation, electronic computer programs, and observing techniques for satellite triangulation.
> At present Dr. Schmid is working on the mathematical and physical problems involved in determining the metric figure of the lunar surface through the use of photography made from moon-orbiting satellites. He has recently been appointed principal investigator for the metric camera system selected by the NASA Apollo Extension Systems Photographic Team. His appointment for this most difficult phase of the lunar mapping program is evidence of his professional stature in the field of photogrammetric geodesy."

One of the more prestigeous honors of the American Society of Photogrammetry is the Fairchild Photogrammetric Award which is given for outstanding contributions to the science of photogrammetry. The Fairchild Photogrammetric Award was presented to Dr. Schmid in 1958 for:

> "Development of techniques and equipment enhancing the usefulness of photogrammetry in solving geometric problems and also in the fields of missile testing and satellite performance."

Another honor presented by the American Society of Photogrammetry is the Talbert Abrams Award. It is given "For authorship and recording of current and historical engineering and scientific developments in photogrammetry". Third prize was awarded to Dr. Schmid in 1963 for his paper on "Precision Photogrammetry, a Tool of Geodesy", and he received the first prize in 1966 for his paper titled "Accuracy Aspects of a World-Wide Passive Satellite Triangulation System".

Awards provide tangible evidence that our accomplishments are recognized and appreciated by our peers. Those awards cited, along with several others earned but unlisted, give testimony to some of the more notable contributions made by Dr. Schmid. For various reasons, however, not all notable contributions are rewarded by plaques or trophies. Some, while not formally recognized, are honored by a higher form of recognition. This is the adoption of the contribution by the community of fellow scientists and the repeated citation of the contribution in scientific literature. Just such a contribution was made by Dr. Schmid in a 1965 paper (1) titled, "A Generalized Least Squares Solution for Hybrid Measuring Systems".

At the time of its publication, least squares techniques, as practiced by most geodesists, were compartmentalized into a number of discrete, apparently unrelated methods. People spoke of the method of condition equations and the method of observation equations as an either/or proposition. Hellmut Schmid and his co-author, Erwin Schmid, demonstrated that all such seemingly different methods could be derived from a single, generalized approach wherein the traditional methods became merely special cases of the generalized approach when certain groups of unknowns in the solution were or were not present. All of the traditional equations could be transformed into observation equation form with all variables treated as weighted observations. Observations with zero weight became pure unknowns and those with infinite weight became constants. All others were allowed to vary according to the magnitudes of their corresponding weights.

The generalized approach greatly simplified the derivation and application of constraint equations and the merging of dissimilar data types into the hybrid least squares systems which are today so commonplace in analytical photogrammetry.

By his accomplishments, publications and awards, the legacy left by Hellmut H. Schmid on photogrammetry in the United States is a matter of record for all to see. What is not as well defined is the effect he had on those with whom he worked. Impressions vary, depending on the nature, duration and depth of individual relationships, but certain common perceptions prevail among those who interacted with Dr. Schmid on a technical level.

Perhaps the foremost perception is of his uncompromising insistence on understanding in detail every aspect of a problem. Superficial familiarity with principles only was never acceptable. He had to know that every step in every algorithm was logical and correct. New ideas and prodecures whether initiated by him or his co-workers were never adopted until they had been thoroughly discussed, dissected, challenged and proven. Those with the temerity to pretend understanding were quickly uncovered by Dr. Schmid's relentless questions. In his eyes, ignorance was never a crime, but trying to hide that ignorance was.

The foregoing is a very brief and general overview of some aspects of Dr. Schmid's legacy on photogrammetry and geodesy in the United States along with some observations of his personality traits as observed by two of his co-workers. An exhaustive treatise on the subject, as evidenced by the numerous publications produced by Dr. Schmid during his years here, would be an enormous task, far beyond the capabilities of only two people. None the less, even in an abbreviated form there can be no doubt to the reader that Dr. Schmid played a major role in the advancement of the sciences of geodesy and photogrammetry not only in the United States, but throughout the world.

(1) Schmid, H.H. and E. Schmid (1965). A Generalized Least Squares Solution for Hybrid Measuring Systems. The Canadian Surveyor, Vol. XIX, No. 1, pp 27–41.

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